Mobile EMC Design Validation

Final Report

Revision 1.0

October 30, 2003

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Contents

I. Introduction

A mechanical shield was designed and manufactured for the purpose of suppressing electro-magnetic interference (EMI) emanating from the mobile die/package environment. The die is a primary source of unwanted radiation and can contribute to system-level inability to meet FCC certification requirements. The radiation signature generated by the die is coupled to adjacent components such as the heat pipe and motherboard, where emissions may be re-radiated and reflected. For example, at certain frequencies, the associated wavelengths may become fractions of the heat pipe geometry and an antenna effect is created. The field strength, or noise amplitude, then becomes a function of how well the heat pipe, etc., “tune-up” to these critical frequencies. Traditionally, the strongest sources of radiation have come from the fundamental core frequency and its harmonics. The grounding points, as part of the cage design solution space, are designed to counter the effect of this phenomenon. Several grounding schemes were modeled for the cage as well as the thermal solution, or Mobile Vapor Chamber (MVC).

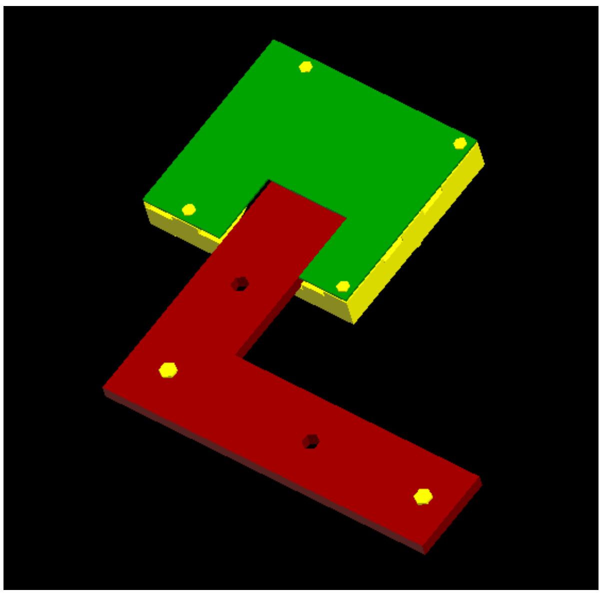
The EMI cage is an optional reference design that will provide a margin of attenuation that OEMs could choose to deploy if necessary. The cage is one of several potential designs that might be used to suppress unwanted emissions. This study is a validation analysis for the particular model designed by Design Process Development (DPD) engineering teams.

II. Methodology

The objective of this study is to validate the cage physical design and measure its EMI-suppression effectiveness. Modeling and simulation methods were used to characterize several different electro-magnetic compatibility (EMC) solutions. Further, grounding points are optimized using numerical modeling tools. Modeling also provides a preview of potential “hot spots,” or areas where current flow is most likely to be channeled. This type of predictive analysis was critical to the overall mobile EMC solution. After the cage mechanical design was chosen and simulations were completed, the radiation profile was measured. A test vehicle was designed to replicate the actual mobile environment. This test board was used to validate several other electrical designs in addition to the EMI cage.

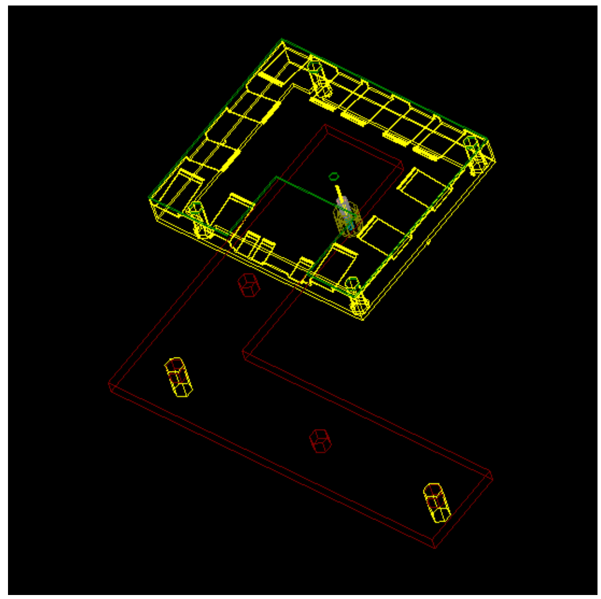
III. Modeling

The Ansoft HFSS* full-wave numerical field solver was used as the primary modeling and simulations tool for analyzing the EMI cage performance. The emissions source was modeled as a coaxial-fed type antenna. Since it is not possible to emulate all conditions found in a die populated with millions of transistors, this type of source is used due to its broadband characteristics and simplicity. A 3D solid model and a wire frame of the assembly are shown in Figures 1 and 2.



Flat shaded solid model

Figure 1



Wire frame model

Figure 2

IV. Grounding

A complete assembly (ground plane, source, grounded standoffs, cage, MVC, and spring plate) was modeled with the MVC grounded at four-points, then two-points. Driven at first by mechanical considerations, the four-point grounding scheme ultimately proved to be the most effective design at attenuating EMI. The mechanical team later determined that the MVC only required two grounded standoffs and modified the design accordingly. Although the plan of record (POR) design shows the two-point grounded MVC, it is necessary to have a 4-point grounded MVC in order for the cage to meet its performance criteria as specified in the Mobile Enabling Design Requirements Document (EDRD).

The results of the 4-point versus 2-point grounded MVC simulations are shown in Figure 3.

These data were later correlated through measurements and are discussed in the "measurements" section of this report.

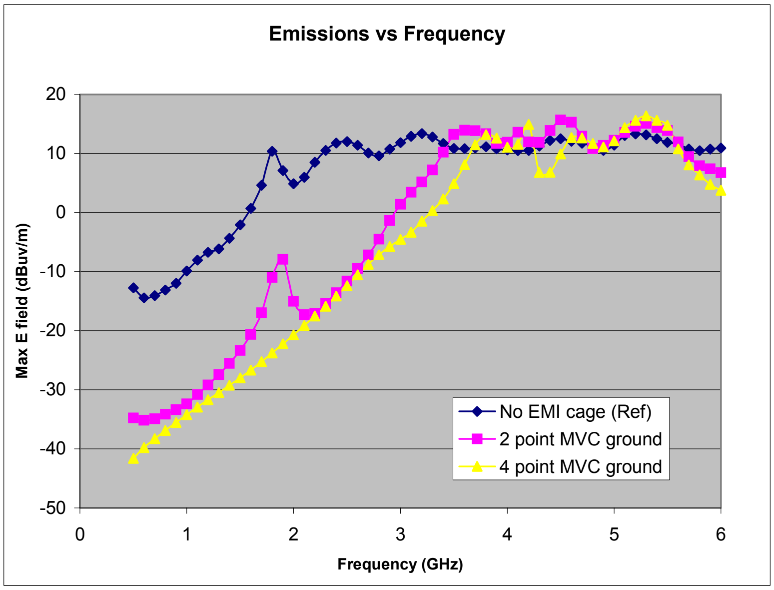


Figure 3

The simulations clearly show the advantage of the 4-point versus the 2-point grounded MVC. The baseline in this case is no EMI cage at all.

An 8-point MVC ground design was also investigated to determine whether better performance could be achieved. The wire frame model for this configuration is shown in Figure 4.

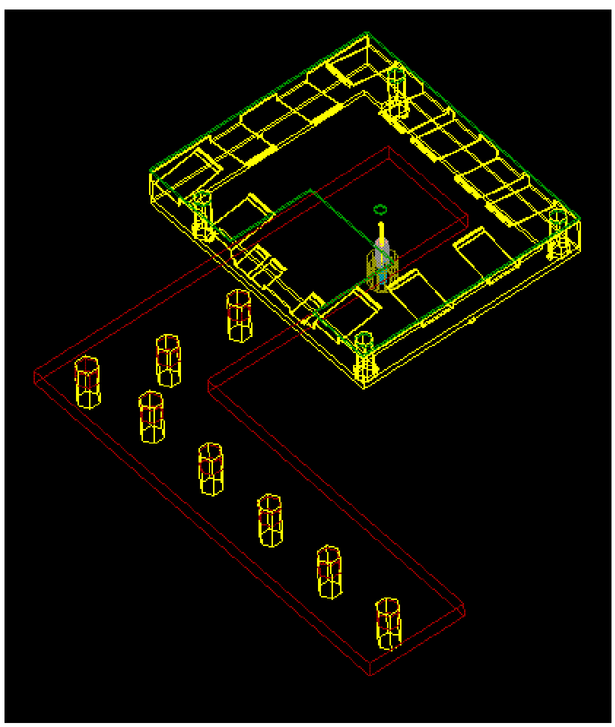


Figure 4

The simulations for an 8-point grounded MVC showed that there is no advantage to adding additional ground points beyond four. The results are shown in Figure 5.

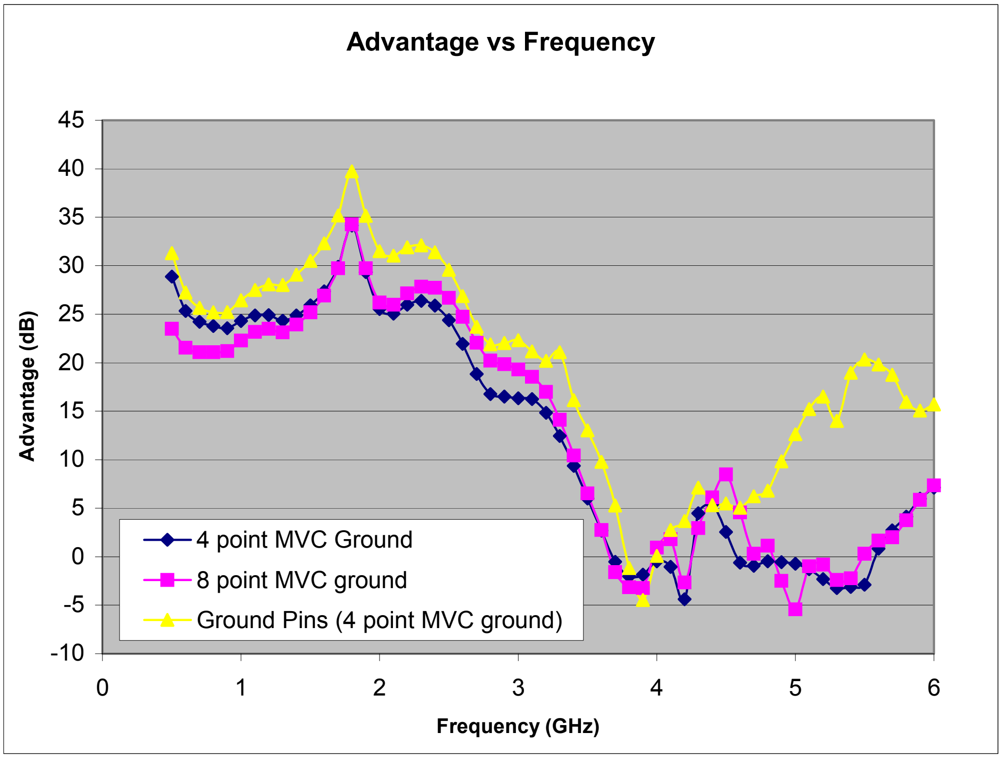
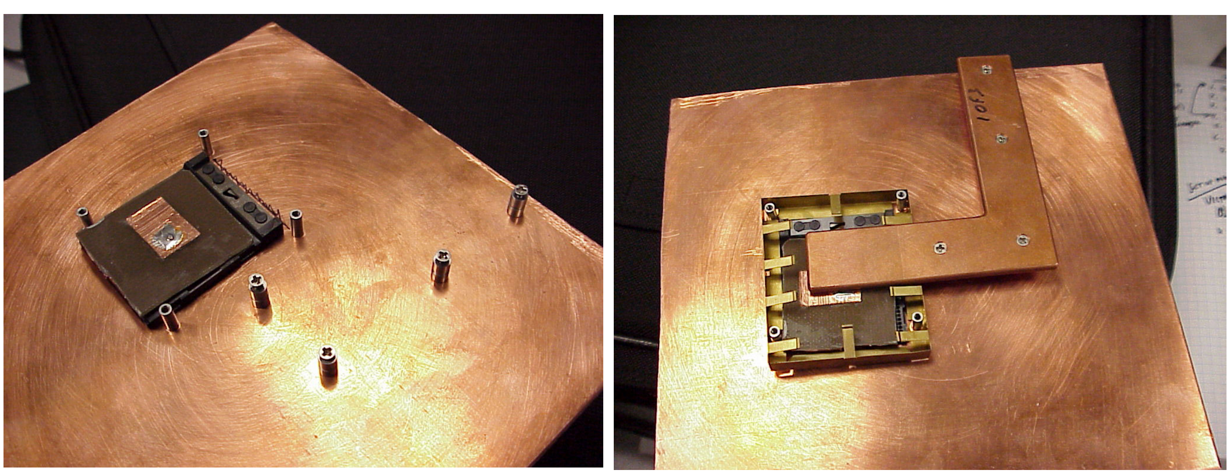


Figure 5

A modeling study to compare the effects of enlarging the cage fingers and placement was also undertaken. Although the outcome was fairly predictable, simulations showed that increasing the surface contact area of the fingers lowered emissions by several dB. The new cage design was adopted based on these results.

V. Measurements

Since the design validation test vehicle was not available at the start of testing, another board was used to characterize grounding schemes and correlate modeling results. A broadband patch antenna was used as the emissions source and is seen with the entire assembly in Figure 6.



Ground plane and assembly w/ no MVC | Cage assembly with MVC

Figure 6

A copper ground plane equivalent in size to the design validation test board was used to support the assembly as well as provide a return path similar to what would be encountered in a mobile environment. A brass EMI cage and prototype solid brass MVC were fixed in place with standoffs that were in turn grounded to the copper plane via screws.

A 3/8" hole was bored through the socket and ground plane to accommodate the patch antenna. Using a Hewlett-Packard* P 8510B network analyzer, a 2-port measurement was taken. Port 1 served as the transmission antenna, port 2 as the receive probe. Three measurements were taken with the receive probe placed in 3-axis orientations, respectively. This approach was done to capture the maximum electric field strength.

The results of the 4-point versus 2-point MVC grounding scheme are shown in Figure 7.

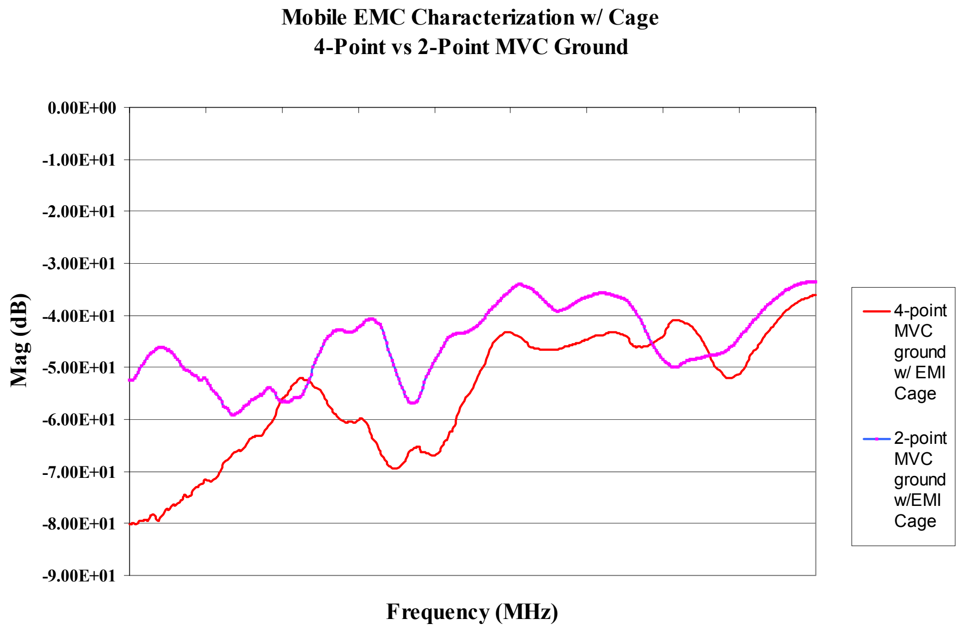


Figure 7

As in the case of the simulations, it is apparent that the 4-point design is more effective at suppressing noise than is the 2-point version. The simulated and measured results match reasonably well. Differences between the two profiles can be attributed to the fact that the sources are modeled differently.

It should also be noted that due to the brass cage (too flimsy) causing assembly problems, and the dissimilar metals creating potential galvanic corrosion issues, the working group decided to adopt stainless steel as the cage material.

VI. Design Validation

The test board and stainless steel EMI cage were used to validate the EMI cage performance. A sample size of sixteen was used in this study.

A gigahertz transverse electro-magnetic mode (GTEM) cell was used to capture the complete radiation profile of the assemblies. This chamber isolates the test vehicle from potential outside sources that could interfere with the measurement and produce misleading results. The GTEM cell is fed by using the HP 8510B network analyzer as both source and receiver. The chamber receives the emissions from all angles, thus obviating the need to rotate the receive probe as in the case of the characterization study described earlier. A photo of the GTEM cell is shown in Figure 8.

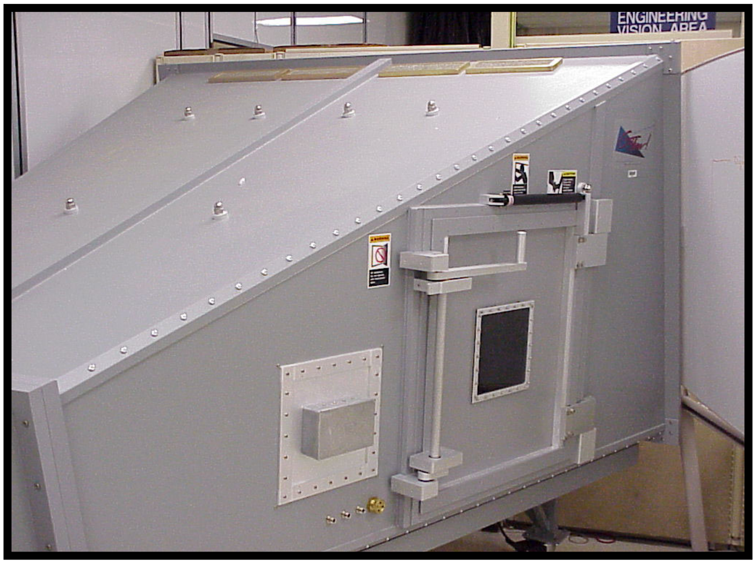


Figure 8

GTEM Cell

The test vehicle is a two-layered board that was designed, in part, to support the thermal solution and EMI cage assembly. The tested assembly (without EMI cage) is shown in Figure 9.

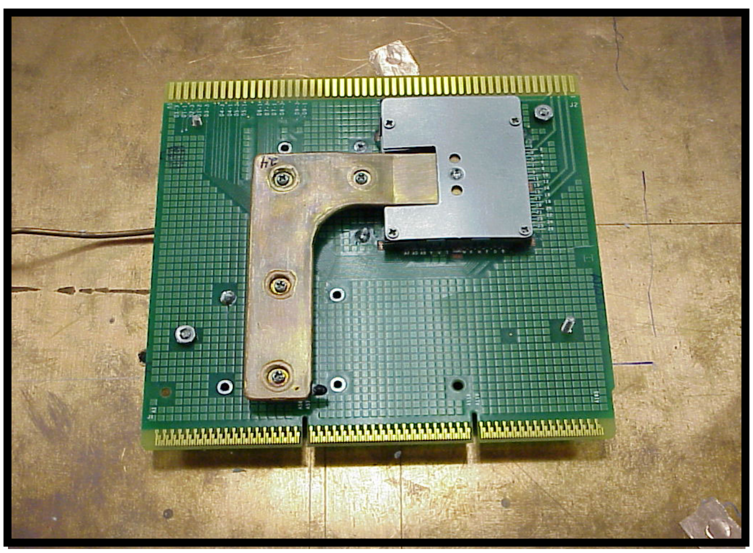


Figure 9

Test Vehicle with Spring Plate, and MVC

VII. Summary

The design validation results show that the DPD-designed EMI cage is effective at suppressing emissions across 80% of the band (1 GHz – 5 GHz), an average of 5 dB.

This conclusion is based on the design validation test vehicle, the equipment used to measure the radiation, and a sample size of sixteen. The attenuation performance of the EMI cage also depends on all cage “feet” making physical contact with the ground pads located on the motherboard, as well as the MVC being grounded at four equidistant points.

Co-planarity issues discovered during rel cycling show that some of the feet are not making contact with the ground pads. A sensitivity study was performed to measure the impact to cage effectiveness due to this problem. The results are outlined below:

VIII. Sensitivity Analysis

The impact to the radiation profile of cage feet not making ground pad contact was studied after rel cycling revealed co-planarity issues. The same test vehicle, equipment, and methodologies were used. Cage feet were removed one at a time to duplicate the non-contact problem. The radiation signature of full feet contact versus one foot removed is shown in Figure 10.

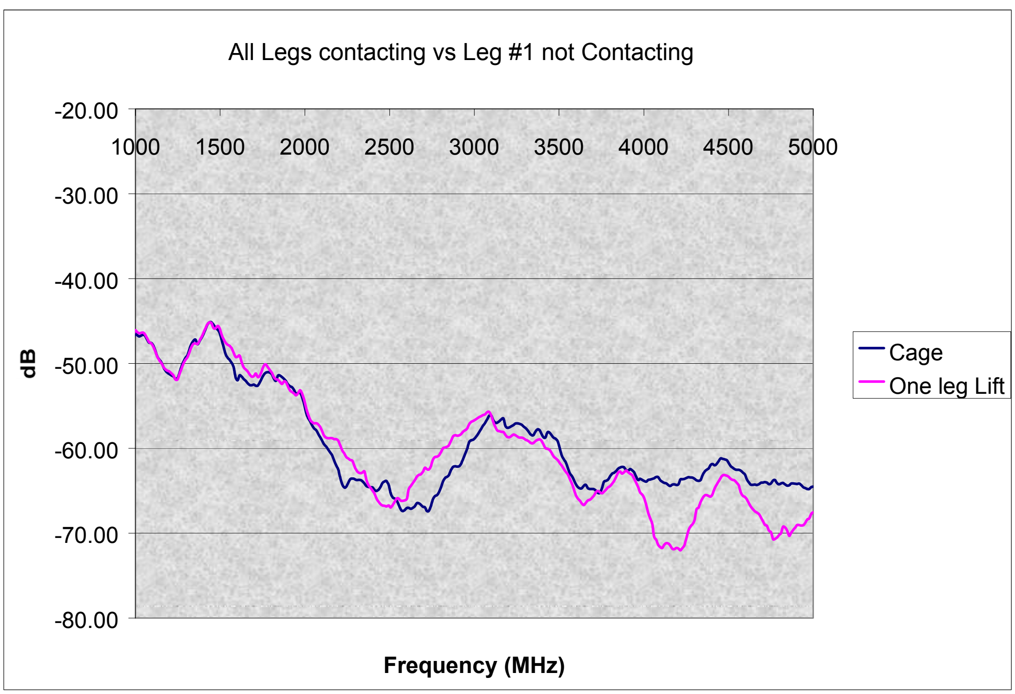


Figure 10

Analysis of a single midwall (see Figure 11) cage foot not making ground pad contact versus full cage contact:

- 2 GHz to 3 GHz: 2 dB loss of shielding advantage (average).
- 4 GHz to 5 GHz: 4 dB gain in shielding advantage (average).

The effects of two adjacent midwall feet not making ground pad contact are shown in Figure 12.

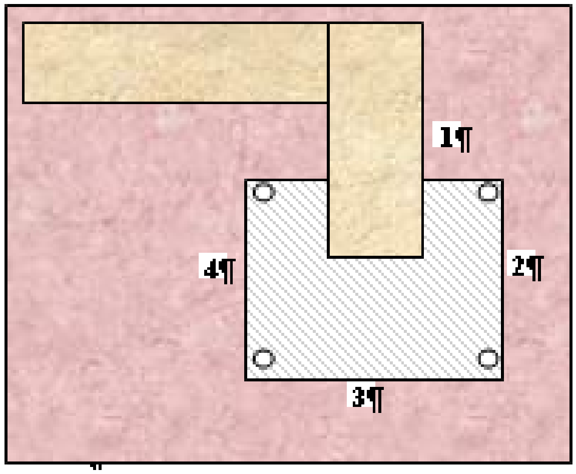


Figure 11

Diagram of assembly layout

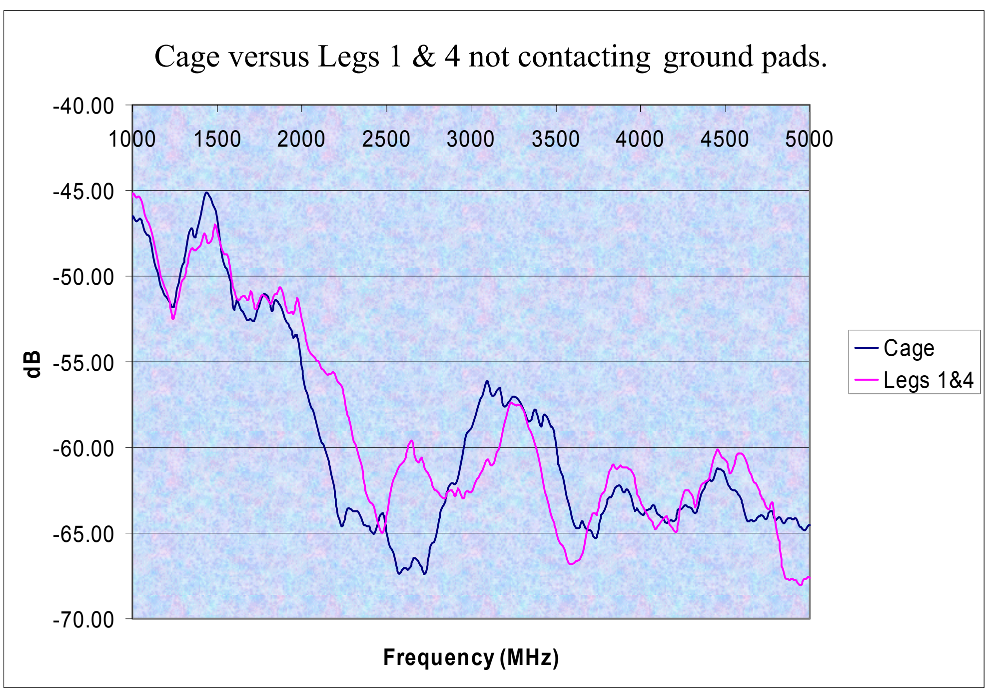


Figure 12

Analysis of adjacent midwall cage feet 1, 4 not making ground pad contact versus full cage contact:

- 1.8 GHz to 2.8 GHz: ~3.5 dB loss of shielding advantage (average)
- 2.8 GHz to 3.6 GHz: ~1 dB gain in shielding advantage (average)

The effects of opposing midwall feet 2, 4 not making ground pad contact are shown in Figure 13.

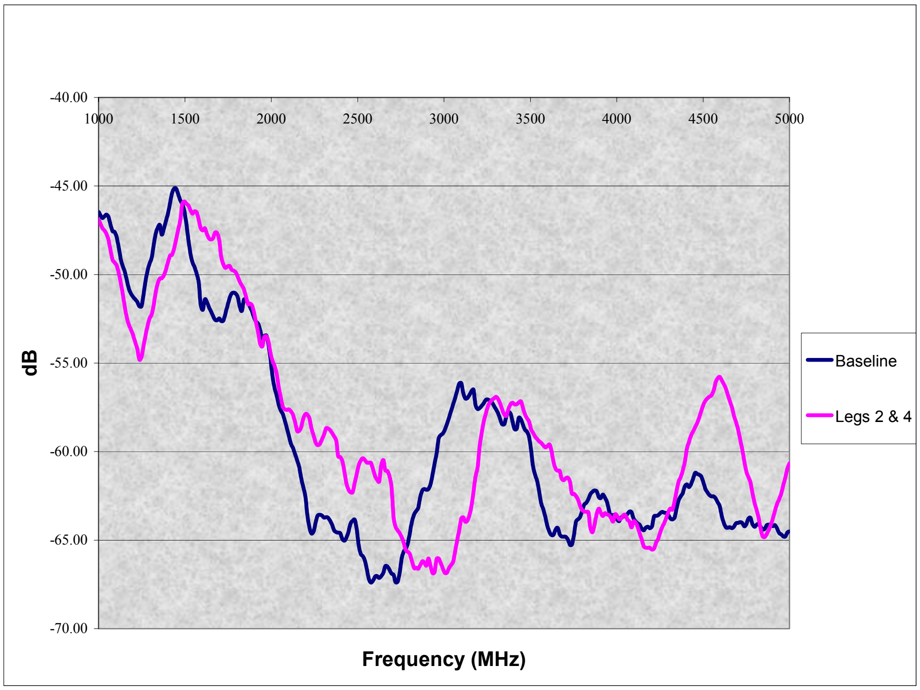


Figure 13

Analysis of opposing midwall cage feet 2, 4 not making ground pad contact versus full cage contact: Average attenuation across the band is limited to <1 dB.

The impact of corner feet not making full ground pad contact is not as significant as are the results for the cases described above (see Figure 14).

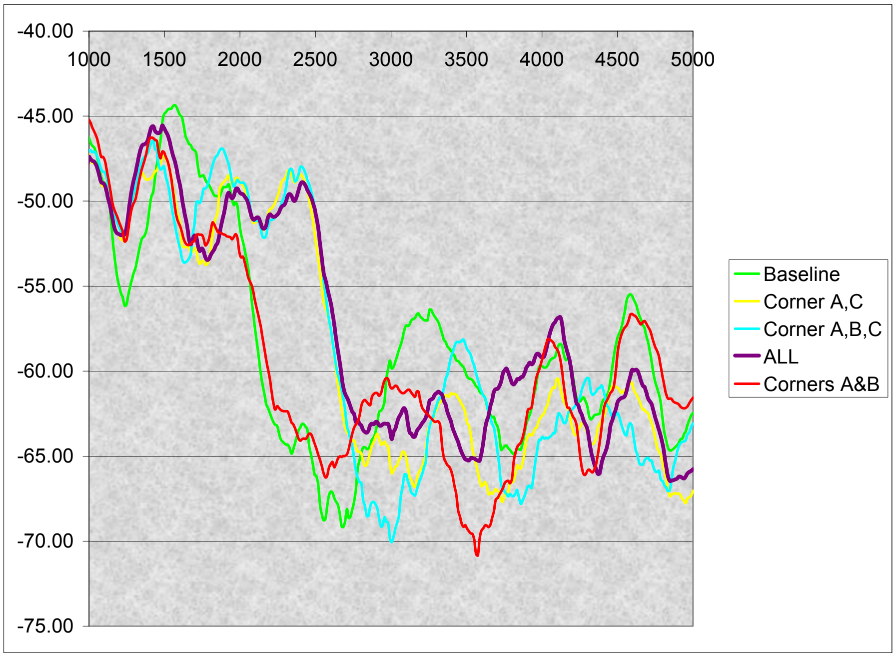


Figure 14

IX. Conclusions

A single cage foot not making ground pad contact has negligible impact on the radiation profile, and hence the cage performance specification.

Two or more cage feet not contacting pads degrade cage attenuation significantly.

The effect of corner feet not contacting pads has negligible impact on cage performance. This is explained by the fact the corners are essentially grounded anyway by virtue of the spring plate/standoff ground.

X. Recommendations

The EMI cage will meet its performance criteria provided that at least three of the four midwall feet make ground pad contact and the MVC is grounded at the four points as shown in the Mobile Enabling Design Requirements Document (EDRD). To help resolve the co-planarity issue, it is recommended that corner feet be removed. This action is expected to allow midwall feet to make full contact with pads.